

Process Specification for Adhesive Bonding

Engineering Directorate

Structural Engineering Division

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National Aeronautics and
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Prepared by:

Signature on file

Michael E. Fowler,
Materials and Processes
Branch/ES4

Approved by:

Signature on file

Brad Files, Branch Chief,
Materials and Processes
Branch/ES4

REVISIONS		
VERSION	CHANGES	DATE
--	Original version	12/95
A	Reformatted entire document to conform to current PRC format. Changed "Class A" and "Class B" to "Level 1" and "Level 2" respectively in accordance with JSC 8500. Removed 1,1,1 Trichloroethane as a cleaning solvent. Removed specific pressure call-outs and referred to material specifications for the correct pressure call-outs.	9/16/97
B	Reviewed per ISO requirements. Removed sentence referring to manufacture of composite parts (Section 6.1)	1/26/2001
C	Removed references to old division name. Added reference document for surface preparation of plastics that describes corona discharge.	11/5/02
D	Reviewed per QMS requirements. Updated reference document numbers. Added bondline thicknesses.	4/15/2005
E	Expanded hardness testing requirement to all adhesives.	5/01/09

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1.0 SCOPE

This document covers the requirements for the adhesive bonding of metals, plastics, and composites in any combination.

2.0 APPLICABILITY

This specification applies to adhesive bonding associated with space flight or space flight-related hardware fabricated under the authority of the NASA/Johnson Space Center (JSC).

3.0 USAGE

This section gives the requirements for the proper use of this process specification.

In accordance with the drawing and part definition requirements of JSC 8500, "Engineering Drawing System Requirements", the standard adhesive bonding process shall be invoked by providing a process note in the applicable drawing or CAD model as exemplified in Figure 1.

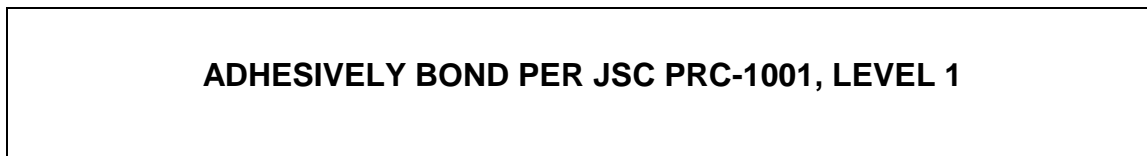


Figure 1. Example of a process note for adhesive bonding.

3.1 LEVEL

The "Level" designator governs the extent to which quality assurance provisions are applied and shall be specified in the process note on the basis of the following definitions:

- a. Level 1 — Level 1 processes shall include the practice of the quality assurance provisions as required by Section 7.1. Whenever invoking these Level 1 provisions, the designer should also consider calling out an NDE process specification on the drawing or CAD model.
- b. Level 2 — Level 2 processes shall include the practice of the quality assurance provisions as required by Section 7.2.

3.2 CURE AND POST-CURE SCHEDULES

Unless otherwise stated on the drawing or CAD model, standard cure and post-cure schedules will be applied to the material in accordance with Sections 6.11 and 6.12. Add special cure or post-cure instructions, if necessary, to the process note on the applicable drawing or CAD model.

3.3 NON-DESTRUCTIVE EVALUATION (NDE)

This specification does not address the application of non-destructive evaluation (NDE) methods. However, when calling for Level 1 processing, the designer should also consider the use of NDE inspection by calling out a separate NDE process specification on the drawing or CAD model.

4.0 APPLICABLE DOCUMENTS

The following documents were used in developing this specification:

JPR 8500.4	<i>Engineering Drawing System Requirements</i>
JPR 5322.1	<i>Contamination Control Requirements Manual</i>

The following documents are invoked as part of this specification:

ASTM D 2093	<i>Standard Recommended Practice for Preparation of Surfaces of Plastics Prior to Adhesive Bonding</i>
ASTM D 2651	<i>Standard Recommended Practice for Preparation of Metal Surfaces for Adhesive Bonding</i>
ASTM D 3933	<i>Standard Guide for Preparation of Aluminum Surfaces for Structural Adhesives Bonding (Phosphoric Acid Anodizing)</i>
ASTM D 1002	<i>Strength Properties of Adhesives in Shear by Tension Loading (Metal-to-Metal)</i>
ISO 13895	<i>Adhesives – Guidelines for the Surface Preparation of Plastics</i>

5.0 MATERIAL REQUIREMENTS

5.1 MATERIAL SPECIFICATIONS

All materials used in the adhesive bonding process shall conform to applicable Government or other specifications.

5.2 MATERIAL OUT-TIME AND SHELF-LIFE

The out-time and shelf-life of the material shall not exceed the shelf-life requirements specified by an applicable MDS. Traceable out-time and shelf-life records shall be kept for materials whose MDS specifies out-time and shelf-life limits. If the material out-time or shelf life exceeds the MDS specifications, then a requalification of the material shall be accomplished in a manner prescribed by the MDS.

6.0 PROCESS REQUIREMENTS

6.1 WRITTEN PROCEDURES AND STANDARDS

For contracted work, refer to the contract for requirements concerning the use of written procedures. Contractors shall also obtain applicable Material Data Sheets (MDS) from JSC Manufacturing before processing.

For work performed at JSC facilities, written procedures shall be used and they shall consist of Detailed Process Instructions (DPI's) selected for use from the DPI-1001-series of work instructions. MDS's shall also be used internally.

6.2 FACILITIES

All bonding operations shall be performed in a controlled environment that is free of contaminants to the extent that bonding operations are not affected. The bonding environment shall have controlled temperature and humidity as required to prevent degradation of the adhesive bond.

6.3 MASKING

Parts and assemblies shall be masked as necessary to protect surfaces not to be bonded from damage, contamination from adhesives, cleaning solutions, or abrasives.

6.4 PREFIT OF PARTS

All detail parts shall be free from burrs, waves, and other imperfections. The detail parts shall provide adequate contact over the entire bonding area.

6.4.1 LEVEL 1 REQUIREMENTS

Where practicable, the detail parts shall be prefitted to determine mismatch. Surfaces not prefitted shall conform to the applicable drawings. Bonding surfaces which conform to all of the following requirements are exempt from prefit:

- a. Both surfaces are nominally flat.
- b. Smallest dimension is 2.00 inches (5.00 cm) or less.
- c. Total bonding surface area is less than 8.00 square inches (51.6 cm²).

Mismatch between detail parts shall not exceed the requirements of Table I.

Table I. Mismatch Requirements

Adhesive Type	Mismatch	% of Bonding Area Allowed	Layers to Use
Film	1 Thickness Layer	NA	1
	Between 1 and 2 Thickness Layers	5	2 ^a
	Between 2 and 3 Thickness Layers	5	3 ^{a,b}
	4 Thickness Layers	0	Rework Parts
Paste	0.000" - 0.005"	100	NA
	0.005" - 0.015"	5	NA
	>0.015"	0	NA
NOTES: a. Gaps or butt splices are not permitted in the adhesive film. Overlaps in the adhesive film up to 0.125 inch (0.318 cm) are permissible. b. Where multiple layers of adhesive are used in a bondline, successive layers shall be stepped approximately 0.25 inch (0.64 cm) (except along the edge of a detail) to fair the bondline. NA Not Applicable			

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6.4.2 LEVEL 2 REQUIREMENTS

The detail parts shall be prefitted prior to bonding to assure non-interference conditions.

6.5 SURFACE CLEANING

The detail parts shall be precleaned to remove oil, greases, inks, etc. using either methyl ethyl ketone (MEK) or Isopropanol in the case of metals. Isopropanol or acetone is acceptable with thermoplastics, thermosets, paints, coatings, etc. which are not compatible with MEK. Silicone-based cutting and forming fluids shall not be used when processing detail parts for bonded assemblies.

6.6 SURFACE PREPARATION

6.6.1 PLASTIC SURFACES

Plastic surfaces shall be prepared for adhesive bonding per ASTM D 2093.

6.6.2 METALLIC SURFACES

Metallic surfaces shall be prepared for adhesive bonding per ASTM-D-2651, in general, and per ASTM D 3933 for phosphoric acid anodizing of aluminum.

The maximum elapsed time between surface priming and the application of adhesive for metallic parts shall be 12 hours.

6.6.3 UNPRIMED SURFACES

Unprimed surfaces shall not be solvent-wiped subsequent to surface preparation and before priming or assembly for adhesive bonding.

6.7 PRIMER APPLICATION

When an adhesive primer is specified on the design drawing, the primer shall be applied to the prepared surfaces to be bonded. The time between surface preparation and primer application, the primer thickness, the primer cure, and the maximum time between primer cure and adhesive application shall be in accordance with the applicable material specification or the manufacturer's recommendation for those materials when a material specification does not exist.

6.8 ADHESIVE APPLICATION

6.8.1 FILM ADHESIVES

Unless otherwise noted on the drawing, or in accordance with mismatch requirements of Table I, one layer of film adhesive shall be applied between faying surfaces. Pressurization and cure of the adhesive shall begin within the out-time of the adhesive.

6.8.2 PASTE ADHESIVES

The adhesive components shall be mixed in accordance with the adhesive material data sheet (MDS), or the manufacturer's recommendations for those materials when a material specification does not exist. The adhesive shall be applied to both faying surfaces. Unless otherwise noted, the adhesive thickness shall be 0.003 – 0.007 inches. Assembly of the parts and pressure application shall take place before the adhesive work-life has expired.

6.8.3 SCRIM CLOTH

One layer of scrim cloth shall be placed between faying surfaces for bondline control when called out on the design drawing. This is only required for paste adhesives.

6.9 ASSEMBLY OF PARTS

Care shall be taken in assembling parts in the curing fixture or bonding jig to assure that the adhesive is not disturbed during the cure period, and that excessive residual stresses in the components are avoided. Shims, caul plates, and other shop tools shall be used as much as necessary to ensure that every adhesive bondline has adequate support and pressure application.

6.10 PRESSURE APPLICATION

Pressure shall be maintained throughout the cure of the adhesive. When heat is applied to the adhesive to promote cure, pressure may only be removed after the assembly cools to at least 150°F (66°C).

6.10.1 VACUUM BAGS

A minimum of 20 inches Hg (0.068 MPa) is required throughout the cure when using vacuum bags unless otherwise indicated in the material specification or on the drawing. The vacuum pressure shall be regularly monitored and recorded for Level 1 processes. The vacuum gauge shall be placed at a position remotely away from the inlet to the vacuum pump line.

6.10.2 AUTOCLAVES

Vacuum is initially needed to seat the diaphragm against the bonded assembly. The pressure differential shall be maintained according to the material specification or drawing throughout the cure. The differential pressure shall be regularly monitored and recorded for Level 1 processes.

6.10.3 DEAD WEIGHT

Dead weight pressure is acceptable for relatively flat adherends. The pressure applied shall be according to the material specification or the drawing throughout the cure when using dead weight loading.

6.11 ADHESIVE CURE

The cure and/or post-cure cycle (time, temperature, and pressure) shall be in accordance with the applicable material data sheet, or the manufacturer's recommendation for those materials when a material specification does not exist. Equivalent cure cycles, when specified on the engineering drawing, may be used provided cured adhesive properties are maintained.

6.11.1 APPLICATION OF HEAT

Heat, if needed, shall be applied by the use of either a circulating air oven, an autoclave, heater blankets or heat lamps.

6.11.2 TEMPERATURE MEASUREMENTS

Temperature measurements shall be recorded by means of thermocouples. The thermocouple shall be placed in the flash area of the adhesive if possible. Otherwise, a thermocouple placed on the part on the outer mold line of the bond is acceptable.

6.12 IN-PROCESS VERIFICATION TESTING

6.12.1 LAP SHEAR TESTS

A minimum of five representative lap shear specimens, conforming to ASTM-D-1002, shall be bonded with each application of adhesive, at the same time, with the same adhesive, in the same equipment, and cured under the same conditions for the assembly they represent. The adherend may be a material other than that specified on the design drawing provided that the specimen surfaces are prepared as necessary to achieve bonded specimens that adequately represent the bonding process. If primer and/or scrim cloth is used in the assembly, then primer and/or scrim cloth shall be used in the specimens.

6.12.2 HARDNESS TESTS

In addition to the lap shear specimens, a hardness specimen shall be potted for in-process verification of adhesive cure. It shall be cured at the same time, with the same adhesive, in the same equipment, and under the same conditions for the assembly it represents. No vacuum or pressure is required. The specimen shall be removed from the bonding equipment and tested according to section 7.1 prior to pressure/temperature removal.

6.13 RECORDS

Pressure, time, and temperature records on each part shall be recorded at least every 15 minutes. These records shall be retained for permanent reference on each lot of material and on each production part for the life of the part for Level 1 processes.

6.14 WORKMANSHIP

Bonded joints shall be of high quality workmanship. Acceptable parts shall be free of defects that adversely affect intended use. Appearance shall be uniform and free of defects as specified herein or on the design drawing. Adhesive shall be evident at the edge of all visibly accessible bondlines.

7.0 PRODUCT ACCEPTANCE TESTING

7.1 LEVEL 1 BONDS

Product acceptance shall be based on a test evaluation of the process control test specimens described in section 6.12 that accompany the product. The lap shear specimens shall be tested per ASTM-D-1002 at room temperature. Hardness specimens shall undergo Shore D or Shore A hardness evaluation as appropriate for the adhesive used.

For product acceptance, the lap shear strengths and hardness results shall meet or exceed the design allowables of the adhesive. If design allowables are not available, vendor-provided allowables (S allowables) with an applied factor of safety are permissible. This factor of safety shall be provided by the engineering organization responsible for process engineering.

The results of product acceptance testing shall be recorded.

7.2 LEVEL 2 BONDS

Product acceptance shall be based upon a visual inspection of the product and a test evaluation of a potted adhesive hardness specimen. Visual inspection shall address bondline uniformity and cure of the adhesive. The hardness specimen shall be as

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described in section 6.12.2 and shall undergo Shore D or Shore A hardness evaluation as appropriate for the adhesive used.

For product acceptance, the hardness results shall meet or exceed an allowable for the adhesive. If an adequate allowable is not available, vendor-provided allowables (S allowables) with an applied factor of safety are permissible. This factor of safety shall be provided by the engineering organization responsible for process engineering.

Lap shear test specimens and process verification records are not required.

8.0 PROCESS QUALIFICATION

Detailed process instructions (DPI's) for the bonding process shall be qualified for each combination of materials used prior to acceptance of finished products. Qualification shall consist of documented test evidence that the procedure for bonding, when performed by suitably trained and proficient operators, is capable of meeting all the requirements of this specification. Any change in procedure or materials shall require requalification.

The qualification testing shall involve a minimum of ten lap shear specimens tested at room temperature to qualify the procedure against strength allowables. If adequate allowables are not available, vendor-provided allowables (S allowables) with an applied factor of safety are permissible. This factor of safety shall be provided by the engineering organization responsible for process qualification.

9.0 TRAINING AND CERTIFICATION OF PERSONNEL

Training of all bonding technicians shall be performed according to written detailed procedures. Proper training shall, at a minimum, be structured in such a way as to ensure that each trainee is capable of producing adhesive bonds that pass Level 1 process verification criteria. Training and certification records shall be kept.

10.0 DEFINITIONS

- a. Faying Surfaces. Pre-bonded, close-fitting surfaces.